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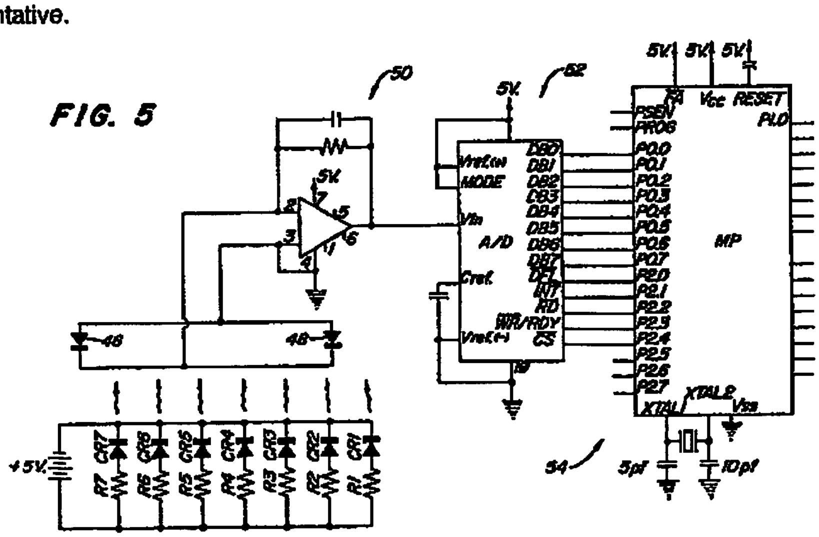
(54) **A signal processing system for an article counter.**

(57) A linear array of light emitting diodes (CR1-CR7) direct a diffuse beam of radiation across the path of seeds dropping down a seed chute and onto two detectors (46, 48) connected in parallel, so that every seed produces a substantially equal area pulse in the output signal from the photo detectors. The signal is amplified (50) and applied to an analog to digital converter (52) producing digital samples at a high rate for processing by a microprocessor (54). The sensor value is subtracted from an offset value corresponding to the sensor signal when no seed is present and the difference signal is repeatedly added to an area signal. The offset value is adjusted from time to time to prevent the difference signal staying persistently negative or persistently positive. Whenever the area signal reaches a threshold value the passage of a seed is indicated and the area signal is decremented by an estimated, area value corresponding to one seed. This estimated area value is adjusted from time to time so as to avoid long term drift in the area value, thereby maintaining the estimated area value accurately representative.

FIG. 5



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A SIGNAL PROCESSING SYSTEM FOR AN ARTICLE COUNTER

This invention relates to a signal processing system for an article sensor for sensing and counting articles such as seeds flowing in a chute in a seed planter, as set forth in the introductory part of claim 1.

Optical seed sensors in which a seed interrupts a radiation or light beam are in the art. Such systems are described in US 4,163,507; US 3,537,091; US 3,928,751; US 3,723,989; US 4,166,948; US 3,974,377; and US 4,246,469. For a number of reasons, such seed sensors have been inaccurate. One problem has been the spatial non-uniformity of the light source and/or of the light detectors so that signals generated by the light detectors vary, depending upon what portion of the light is interrupted. Means are described below which overcome this problem but the present invention is concerned with a different problem arising in the processing of the sensor signal. In the prior art it been customary either to compare the sensor signal with a threshold to determine when an article is present (e.g. US 4,166,948) or to derive a pulse fro the sensor signal by a differentiating circuit (e.g. US 4,163,507). In either event the system is liable to count a plurality of seeds simultaneously traversing the light as a single seed.

An alternative signal processing system, in accordance with the introductory part of claim 1 is known in the art in US 900 718, wherein an integrated signal is periodically discharged by charges to provide an article count. However no automatic adjustment of these charges is made in dependence on changes in average article size. It is necessary to perform a calibration operation periodically and manually adjust a resistor which determines the size of the decrementing charge.

The object of the present invention is to provide an improved processing system which can adjust automatically to changes in particle size.

The signal processing system according to the invention is characterized as set out in claim 1.

As will be described below, the system is arranged to compensate automatically for changes in the steady-state output of the detector and compensates automatically for gradual changes in average article or seed size.

The system be used to determine the time spacing between the articles for use in testing of planter seed metering devices.

The system can be arranged to ignore articles too small to be the ones monitored.

The sensor itself preferably includes an array of infrared LEDs extending across one side of an article or seed conduit. The array generates a substantially diffuse and uniform radiation beam which is detected by planar photo diodes which extend across the opposite side of the conduit. A pair of oppositely facing mirrors extend between the array and the photo diodes and reflect the LED radiation back into the conduit. Slits between the array and the conduit and between the conduit and the photo diodes narrow the beam which the articles or seeds traverse and prevent extraneous radiation from impinging upon the photo diodes.

With the diffuse, uniform and extended radiation beam produced by the LED array, all articles or seeds passing through the detector have nearly equal effect on the amount of radiation received by the photo diodes, even when multiple articles or seeds are tightly bunched together, even when multiple articles pass simultaneously through the beam, and even when one article is (as viewed perpendicularly to the array) in the partial "shadow" of another article which is between the one article and the array. The signal from the photo diodes has a substantially linear relationship to the total amount of radiation which falls on them, and thus, also has a similar (but inverse) relationship to the quantity of articles or seeds which interrupt the beam inside the detector.

The signal from the photo diodes is processed by an electronic unit which includes a current-to-voltage converter, an A/D converter and a microprocessor. The microprocessor executes an algorithm which accurately counts the articles which pass through the beam by repetitively integrating a value derived from the signal from the photo diodes. The algorithm compensates for changes in the steady-state signal produced by the photo diodes when no articles are in transit through the beam, and determines the number of articles in groups of articles which simultaneously pass through the beam. The algorithm also compensates for gradual changes in average article size.

The invention will now be described, in more detail, by way of example and with reference to the accompanying drawings, in which:

Fig. 1 is a sectional side view of a beam-type article or seed sensor;

Fig. 2 is a partial sectional view taken along line 2-2 of Fig. 1, with parts removed for clarity;

Fig. 3 is a view of the photo diode mounting plate looking towards the LED array with the photo diodes removed;

Fig. 4 is a side view of one of the radiation transmitting windows of the sensor of Fig. 1;

Fig. 5 is an electrical schematic of a signal processing system embodying the present invention;

Fig. 6 is a signal timing diagram illustrative of signals which can be produced by transit of seeds through the sensor of Figs. 1 - 4; and

Figs. 7a - 7e contain a logic flow diagram of the signal processing algorithm executed by the signal processing unit of Fig. 5.

An article or seed sensor 10 includes a conduit 12 which forms an article or seed flow passage 14 and which receives a sensor module 16. Sensor module 16 includes a top 15 and a base 20, each having rectangular openings 22 and 24 which register with the seed flow passage 14.

The sensor module 16 also includes opaque end plates 26 and 28 (see Fig. 2), opaque side plates 30 and 32, mirrors 34 and 36, and glass windows 38 and 40, all held in grooves on the inner surfaces of the top 18 and base 20.

The side plate 30 supports an array 42 (at least 3 and preferably 7) of radiation generators CR1 - CR7. Various known radiation emitting devices could be suitable, but infrared light generators are preferred because of the dust-penetrating ability of infrared radiation. A suitable device is the Siemens No. SFH 407-3 GaAs infrared light emitting diode (LED). Preferably, plate 30 is a PC board with conductive strips forming electrical connections with the LEDs CR1 - CR7 mounted thereon.

As best seen in Fig. 2, this array of LEDs extends substantially across the entire width of the seed flow path 14 and transversely to the direction of seed flow which is downwards, viewing Fig. 1. The radiation beam generated by each LED has a wide angular dispersion approaching that of a point light source mounted on a planar surface. Thus, the beams from adjacent pairs of the LEDs intersect with each other well before they reach the nearest window 38. This assures that all areas in the seed flow path between windows 38 and 40 are illuminated.

The end plate 32 is preferably made of opaque black plastic and has a rectangular recess 44 which receives a pair of flat planar detectors or photo diodes 46 and 48 for generating electrical signals in linear response to radiation received thereby. End plate 32 also includes a longitudinal slot or aperture 45, which has a width which is smaller than a typical dimension of the articles or seeds being sensed, (preferably 1 mm wide). Thus, slot 45 permits only a portion of the radiation from LED array 42 to impinge upon detectors 46 and 48. The slot reduces the amount of ambient radiation (other than from array 42) which impinges upon detectors 46, 48. Slot 39 in window 38 narrows the angular spread of beam B to prevent the beam from reflecting off of articles or seeds which are outside of a small portion of the volume surrounded by mirrors 34 and 36 and windows 38 and 40.

Any detector which is responsive to the radiation generated by array 42 is suitable; however, in the case where infrared LEDs are used, then photo diodes, such as Type No. SP-652S made by Centronic, Inc., or the equivalent, are preferred. The end plate 32 and photo diodes 46 and 48 are positioned parallel to and spaced apart from the array 42 so that seeds traveling through seed passage 14 must pass between the array 42 and the photo diodes 46 and 48, thus varying the amount of radiation received thereby. The photo diodes 46 and 48 thus form a planar radiation detector which extends transversely with respect to the seed flow path across the longer dimension of the rectangular openings 22 and 24.

The radiation reflecting mirrors 34 and 36 are positioned parallel to each other on opposite sides of the seed flow path. Each mirror extends from an edge of side plate 30 to an edge of side plate 32. The mirrors 34 and 36 are preferably silvered or reflectively coated on the sides facing away from the seed flow path so that the reflective coatings will not be damaged due to abrasive contact with seeds.

Viewing Fig. 2, radiation from LEDs CR1 to CR7 which would otherwise be directed out of the path traversed by the seeds is reflected back into the seed path by mirrors 34 and 36. This has an effect similar to having the array 42 extend laterally beyond the plane of mirrors 34 and 36. The array 42 and the mirrors 34 and 36 cooperate to form a substantially diffuse, uniform and essentially extended radiation beam which enables the present detector to, in essence, "look behind" one seed to sense a seed which would otherwise be in the shadow of a seed which is closer to array 42.

The glass window 38 is spaced apart from and parallel with respect to the LED array 42 and is transparent to the infrared radiation emitted thereby and has its inward facing surface in line with an inner wall 50 of the conduit 12. The window 38 extends from mirror 34 to mirror 36. As best seen in Figs. 1 and 4, window 38 has an opaque coating or mask 37 on the side nearest the LED array 42. A longitudinal gap 39 in the mask 37 forms a slit aperture, preferably around 1 mm wide, through which the radiation from array 42 is transmitted. The gap 39 extends the full length of window 38 between mirrors 34 and 36.

The window 40 is positioned parallel to the window 38 on the opposite side of the seed flow passage 14. The transparent glass window 40 has a radiation-blocking opaque mask 41 on the side facing away from seed passage 14. A longitudinal gap 43 in the mask 41 forms a slit aperture, preferably around 2 mm wide, through which the radiation from LED array 42 is transmitted. The gap 43 also extends the full length of

window 40 between mirror 34 and 36.

As best seen in Fig. 5, each of LEDs CR1 - CR7 is connected in series with a corresponding resistor R1 - R7 and the resistor/LED pairs are then connected in parallel to a +5 volt power supply. The two detectors 46 and 48 are electrically connected in parallel. As best seen in Fig. 2, the resistors R1 - R7 may be located in the spaces between mirrors 34 and 36 and end plates 28 and 26. The current signal from detectors 46 and 48 is received by a current-to-voltage amplifier 50. Preferably, amplifier 50 includes an operational amplifier (such as an RCA No. CA 3160), a 44 pf feedback capacitor C1 and a 562 kOhm feedback resistor. Amplifier 50 provides an analog voltage to the Vin input of conventional analog-to-digital converter 52 (such as a National Semiconductor ADC 0820). A/D converter 52 provides an 8-bit digital signal (representing the voltage at Vin) to the P0.0 to P0.7 inputs of microprocessor (micro) 54 (such as an Intel 8051). The A/D converter 52 starts an A-to-D conversion in response to a flag signal received at its $\overline{WR}$ /RDY input.

The micro 54 is supplied with a 12 MHz frequency from crystal oscillator 56. This frequency is divided internally to provide a 1 mHz machine instruction frequency. A timer (not shown), which is internal to the micro 54, counts the machine cycle frequency and generates a flag signal every 100 micro-seconds.

The micro 54 causes a new A/D conversion to be performed by converter 52 and executes an algorithm or instruction set every 100 micro-seconds in response to the occurrence of the flag signal.

The algorithm or program executed by micro 54 is best understood with reference to the signal timing diagrams of Fig. 6 and to the logic flow diagrams of Figs. 7a - 7e.

Turning first to Fig. 6, the upper waveform is typical of an oscilloscope trace of the voltage at the Vin of A/D converter 52 when articles such as ball bearings are passed through the detector 10. The signal pulses at 60, 68 and 70 are representative of the signal produced by a single article passing through the detector 10. The signal pulses at 64, 66, 74 and 76 are representative of 2 articles passing through the detector 10. Pulse 74 is produced when the 2 articles pass sequentially, one immediately following the other. Pulse 64 is produced when the second article enters the radiation beam before the first article leaves it. Pulses 64 and 66 represent situations where 2 articles pass through the detector nearly simultaneously, or in very close proximity to each other, regardless of the orientation of the article grouping. Pulse 62 is produced by 3 articles passing nearly simultaneously through the detector 10. Pulse 72 is produced by 4 articles passing nearly simultaneously through the detector 10. The paranthetical numbers inside the waveform pulses are proportional to the area circumscribed by the pulses in arbitrary units. These waveforms illustrate that the area circumscribed by each is related to the number of articles which produce the waveform.

It should be noted that a differentiating-type counter would probably incorrectly interpret pulses 62, 64, 66 and 72 as being produced by 1, 1, 2 or 3, and 3 articles, respectively, whereas, these pulses are actually caused by groups of 3, 2, 2 and 4 articles, respectively. The following signal-processing algorithm correctly interprets these pulses as being caused by article counts of 3, 2, 2 and 4, respectively.

Turning now to Figs. 7a - 7e, the algorithm begins at step 100 by setting a HALF_UNIT value equal to 1/2 of a UNIT value which is initially equal to 768 to represent an initial estimate of the typical area circumscribed by the signal pulse produced by passage of a single article through the sensor apparatus. Such a pulse is shown at 60 of Fig. 6. Then, step 102 causes the algorithm to pause until the internal timer generates a flag signal at 100 micro-second intervals. Upon generation of the flag signal, step 104 causes A/D converter 52 to perform a conversion and input a new digital Vin value (INPUT) into the micro 54. Then, in step 106, a SIGNAL value is set equal to OFFSET - INPUT, where OFFSET represents the possibly slowly varying steady-state level of Vin (normally 4 volts) when no seeds are interrupting the beam B. Thus, when a seed is in the beam B, the SIGNAL value will normally be positive and will represent the vertical depth of the Vin signal (see Fig. 6) at each sampling instant relative to the normal or steady-state value of Vin when no seed is in the beam B.

However, the SIGNAL may be negative if no seed is present and if the OFFSET value is lower than the current steady state Vin level. In this case, step 108 directs the algorithm to steps 136 - 144. In step 136, an DNTIME timer is initialized to a value representing a 12 msec interval. Step 138 decrements an UPTIME timer. Step 140 routes the algorithm to step 150 if the UPTIME timer has not counted out; otherwise, in step 142, the OFFSET value is incremented by 1 binary count. Finally, step 144 sets the UPTIME timer to a 3 msec value. Thus, the OFFSET value will be incremented if the SIGNAL value remains negative for more than 3 msec.

If SIGNAL is not negative, then step 108 directs the algorithm to step 110 which determines if SIGNAL = 0. If yes, it means that no seed is present and that the current OFFSET value appears proper and steps 146 and 148 set the UPTIME and DNTIME timers to values representing 3 milliseconds and 12 milliseconds, respectively. If no, then it means it is possible that a seed or seeds are in the beam B.

In step 112, the UPTIME timer is set to a 3 millisecond value. The DNTIME timer is decremented in

step 114. Then, step 116 determines if the DNTIME timer value is greater than zero. If no, it means that SIGNAL has been positive for 12 milliseconds and the OFFSET value is adjusted by 1 digital count in step 118, and the DNTIME timer is again set to a value representing 12 milliseconds. If in step 116 the DNTIME counter is greater than zero (which means that SIGNAL has been positive for less than 12 milliseconds), or after step 120, the algorithm proceeds to step 122.

In step 122, a PULSE value (initially zero), is numerically integrated by adding to its previous value the current SIGNAL value. Thus, the PULSE value represents an area circumscribed by the graphical representation of the Vin signal pulses shown in Fig. 6.

Step 124 determines whether SIGNAL equals a digital count of 2 or 1. If not, it means that SIGNAL must be greater than 2 since steps 108 and 110 have already determined that SIGNAL is non-negative and non-zero. In this case, it means that a seed or seed group has begun or remains in transit through the beam B and the algorithm proceeds to step 126 where a P1.1 flag (initially zero) is set equal to 1. Then, step 128 determines whether the area value PULSE is greater than or equal to the HALF_UNIT value (which represents 50% of the typical area of the signal pulse produced by transit of a single seed.) If PULSE has not attained this 50% area value, then the algorithm returns to step 100 for updating of the SIGNAL value in step 106 and further integration of the PULSE value in step 122. However, if PULSE exceeds the 50% area value, then step 130 causes the signal at micro output port P1.0 to toggle to indicate transit of a seed through the sensor. Next, step 132 increments a QUAN value (initially zero) which represents the total number of seeds in seed group which may be passing through the sensor. Then, step 134 sets the area value, PULSE, equal to (PULSE -UNIT) and returns the algorithm to step 100. This makes the PULSE value negative so the condition of step 128 will again be met only upon additional repetitive integration of the PULSE value by step 122 due to transit of further seed or seeds of a seed group.

Referring back to step 124, if the SIGNAL value has a digital value of 2 or 1, it is interpreted to mean that the passage of a seed or a seed group through the beam B has just begun or has just been completed (or that noise or negative drift of the bias level has occurred) and the algorithm proceeds to step 150 and further integration of the PULSE value is prevented. Step 150 determines if a P1.1 flag value (initially zero) is equal to 1. If P1.1 does not equal 1, then it means either that step 126 has not yet been executed because there is no convincing evidence (i.e., SIGNAL>2) that a seed is in transit and that P1.1 was previously cleared to zero at step 151 when the last seed transit was finished. In this case, the algorithm is directed to steps 208 - 212 wherein the PULSE and QUAN values are cleared and the algorithm is returned to step 100. If, on the other hand, the P1.1 value equals 1 in step 150, then it means a seed transit is just ending and the algorithm is directed to step 151 where P1.1 is cleared.

In step 152, the area value PULSE is compared to the HALF_UNIT area value. If PULSE is less than HALF_UNIT, then the algorithm proceeds to step 160. However, if PULSE is not less than HALF_UNIT, then step 154 causes the micro output port P1.0 to toggle (as at step 130) to indicate transit of a seed through the sensor. Then, the total seed number value, QUAN, is incremented in step 156, and the PULSE value is reset to a negative value in step 158 (as in step 134).

At this point, it is helpful to understand how the value, PULSE, varies as a single seed passes through the beam B. Initially, the PULSE value will be zero. Then, as a seed transit produces a waveform, such as 60 of Fig. 6, the PULSE value will be repetitively integrated by the addition of the increasing SIGNAL values in step 122 until PULSE equals the HALF_UNIT value, at which time, the Vin level reaches a minimum and the SIGNAL value reaches a maximum. Then, step 128 operates to direct the algorithm through steps 130 - 134, wherein step 134 resets the PULSE value to a negative value, typically equal to -(HALF_UNIT), if the UNIT value accurately represents the area circumscribed by the waveform pulse being processed. Then, during the remainder or second half of waveform 60, step 122 integrates the PULSE value back up so that when Vin returns to its steady state value and when SIGNAL reaches zero, the PULSE value will return to zero, again assuming that the UNIT value was an accurate estimate of the total area of pulse waveform 60.

Now, if, in fact, the estimated area value UNIT, was too large, then at the end of a seed transit, the PULSE value in step 122 will be slightly negative. Thus, as described later in detail, this slightly negative PULSE value will be utilized in algorithm portion 180 to slightly reduce the TOTAL value. Since the TOTAL value is stored as a 3-byte value (each byte consisting of 8 bits) and since, by definition, the UNIT value is that which is stored in the 2 most significant bytes of TOTAL, therefore, a reduction in the TOTAL value also reduces the UNIT value, thus making the UNIT value more closely approximate the typical or average signal pulse area produced by a single seed transit. Similarly, if the estimated area value, UNIT, was too small, then the PULSE value in step 122 (at the end of pulse area integration) will be slightly positive. This will cause the algorithm portion 180 to slightly increase the TOTAL value, and will cause a corresponding increase in the UNIT value for use during the next seed transit. Thus, by adjusting the TOTAL and UNIT values, the algorithm automatically compensates for changes in the average size of seeds passing through

the sensor.

Steps 160 - 210 will now be described. To summarize, steps 160 - 210 operate to make major adjustments (if ever needed) in the estimated signal pulse area value, UNIT, so that the correct values of UNIT and HALF_UNIT will be utilized in steps 100, 128, 134, 152 and 158.

Steps 160 - 168 determine whether the QUAN value (initially zero or set in steps 132 or 156) equals 0, 1, 2, 3 or more (representing signal pulses caused by the transit of something less than a seed (QUAN = 0) or by the transit of seed groups consisting of 1, 2, 3 or more seeds, respectively).

Under normal conditions, the signal pulse which is produced most often will be that which is caused by the transit of a single article or seed through the beam B, thus QUAN will most often be equal to 1 (assuming a reasonably accurate UNIT value). In this case, step 162 will route the algorithm to a portion of the algorithm represented by 180 which has the effect of deriving an updated TOTAL value equal to the sum of the current TOTAL and residual PULSE values. Since, as previously described, the TOTAL value is related to the UNIT value, this, in effect, repetitively adjusts the UNIT value so that it continues to represent the signal pulse area caused by transit of a single seed. Then, step 182 decrements a ONES counter (initially 256 or reset to 256, at step 200). If the ONES counter is decremented to zero, then step 184 recognizes this overflow condition and routes the algorithm to steps 198 - 210 which reset the ZEROES, ONES, TWOS, THREES and FOURS counters to 256 and which clear to zero the PULSE and QUAN values so that they can be redetermined by steps 100 - 158. If the ONES counter has not overflowed, then the algorithm is directed by step 184 directly to steps 208 and 210. Thus, if the UNIT value accurately represents the estimated single seed pulse area, the algorithm will most often incrementally adjust the UNIT value (via adjustment of the TOTAL value in 180), and will continuously reset the ZEROS, TWOS, THREES and FOURS counters in steps 198, 202, 204 and 206 so that the algorithm will never execute step 178 or step 172 which either divides TOTAL by 2 or multiplies TOTAL by 2.

However, if the UNIT value is too large, then the QUAN value will most often be zero because steps 128 and 152 would prevent incrementing of the QUAN value in steps 132 or 156. In this case, the algorithm will most often be directed by step 160 to step 174 which decrements the ZEROES counter. If this situation persists, then step 174 will eventually decrement the ZEROS counter to zero, whereupon step 176 will recognize this overflow condition and will route the algorithm to step 178. Step 178 reduces the TOTAL value by 50% (for example) and thus, causes a corresponding reduction in the UNIT value. Eventually, this process will reduce the UNIT value to a level whereby single seed transits will produce QUAN values equal to 1.

If the estimated pulse area value, UNIT, is too low, then the most often occurring single seed transits can result in QUAN values of 2, 3 or more. In this case, steps 164 and 166 will route the algorithm to steps 186, 192 or 194 where TWOS, THREES and FOURS counters (initially 256 or reset to 256 in steps 202 -206) are decremented. When any of these counters reaches zero, then steps 188, 194 or 170 will recognize the overflow condition and will route the algorithm to step 172. Step 172 multiplies the TOTAL value by 2, thus causing an increase in the estimated area value, UNIT. Otherwise, steps 188, 192 and 170 will route the algorithm directly to steps 208 and 210 and thence, back to step 100.

It has been found that it is adequate merely to double the TOTAL value (such as in step 172) regardless of which of the TWOS, THREES or FOURS counters overflows first. However, it would be possible to change the TOTAL value by different amounts, depending upon which counter overflowed first by adding separate TOTAL recalculating steps after each of steps 188, 194 and 170.

Another alternative would be to route the "NO" branch from step 162 directly to step 186 (eliminating steps 164 - 170, and steps 192 - 194) and to make the initial and reset value of the ONES counter smaller than that of TWOS counter so that under normal circumstances, the ONES counter will continue to overflow before the TWOS counter (which, in this case, would be decremented upon the transit of any seed group producing a QUAN value of 2 or more.)

At the end of this "Detailed Description" are object and source code listings of the computer program which is illustrated by the logic flow chart of Figs. 7a - 7e. The source code listing includes labels such as READ: and ADDPULSE:, which corresponds to similar labels in the flow chart. There also follows a cross-reference symbol table listing which includes various acronyms used in the flow chart and program listing.

The signal-processing algorithm described herein could be used in conjunction with another type of article or seed sensor as long as the sensor can generate a signal which varies substantially linearly with the number of articles or seeds within it.

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MCS-51 MACRO ASSEMBLER    SEED21

ISIS-II MCS-51 MACRO ASSEMBLER V2.1
OBJECT MODULE PLACED IN :F1:SEED21.OBJ
ASSEMBLER INVOKED BY;  ASM51 :F1:SEED21.A51

LOC  OBJ            LINE     SOURCE
                       1     $ XREF PAGELENGTH(62) DEBUG ERRORPRINT NOMACRO
                       2
                       3     ; THIS PROGRAM WAS LAST EDITED AT 5:16 PM ON APRIL 20, 1984.
                       4     ; WRITTEN BY KENNETH FRIEND
                       5
                       6     ; THIS PROGRAM WILL RUN THE 8051 MICROCOMPUTER USED IN THE PLANTER SEED SENSOR.
                       7
                       8
 001E                  9     THREE_MILLISECONDS EQU 3*10
 0078                 10     TWELEVE_MILLISECONDS EQU 12*10
                      11
 REG                  12     UPTIME           EQU     R0
 REG                  13     DNTIME           EQU     R1
 REG                  14     QUAN             EQU     R2
 REG                  15     PULSE_HI         EQU     R3
 REG                  16     PULSE_LO         EQU     R4
 REG                  17     TOTAL_HI         EQU     R5
 REG                  18     TOTAL_HI         EQU     R6
 REG                  19     TOTAL_LO         EQU     R7
 REG                  20     UNIT_HI          EQU     TOTAL_HI
 REG                  21     UNIT_LO          EQU     TOTAL_HI
                      22
----                  23             DSEG     AT      30H
0030                  24     TEMP:            DS      1
0031                  25     OFFSET:          DS      1
0032                  26     SIGNAL:          DS      1
0033                  27     HALF_UNIT_HI:    DS      1
0034                  28     HALF_UNIT_LO:    DS      1
0035                  29     ZEROS:           DS      1
0036                  30     ONES:            DS      1
0037                  31     TWOS:            DS      1
0038                  32     THREES:          DS      1
0039                  33     FOURS:           DS      1
003A                  34     GLITCHES:        DS      2
  003A                35     GLITCHES_HI      DATA    GLITCHES
  003B                36     GLITCHES_LO      DATA    GLITCHES+1
003C                  37     SINGLES:         DS      2
  003C                38     SINGLES_HI       DATA    SINGLES
  003D                39     SINGLES_LO       DATA    SINGLES+1
003E                  40     DOUBLES:         DS      2
  003E                41     DOUBLES_HI       DATA    DOUBLES
  003F                42     DOUBLES_LO       DATA    DOUBLES+1
0040                  43     TRIPLES:         DS      2
  0040                44     TRIPLES_HI       DATA    TRIPLES
  0041                45     TRIPLES_LO       DATA    TRIPLES+1
0042                  46     QUADRUPLES:      DS      2
  0042                47     QUADRUPLES_HI    DATA    QUADRUPLES
  0043                48     QUADRUPLES_LO    DATA    QUADRUPLES+1
                      49
                      50     $EJECT
```

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MCS-51 MACRO ASSEMBLER     SEE021
LOC  OBJ            LINE     SOURCE
                      51              CSEG    AT       000H
                      52
0000 2100             53              AJMP    START
                      54
0100                  55              ORG     100H
0100 E4               56     START:   CLR     A                ; \
0101 787F             57              MOV     R0,#7FH          ; : CLEAR RAM
0103 F6               58     LOOP:    MOV     @R0,A            ; :
0104 D8FD             59              DJNZ    R0,LOOP          ; /
                      60
0106 0D               61              INC     UNIT_HI          ; INITIALIZE UNIT_DB TO 0100H
                      62
0107 758C9C           63              MOV     TH0,#256-100     ; \
010A 7589BA           64              MOV     TMOD,#10111010B  ; : SET UP TIMER TO SET TF0 EVERY 100 MICROSECONDS
010D D28C             65              SETB    TR0              ; /
                      66
                      67     INITIALIZE:
010F 7003             68              MOV     UNIT_HI,#03H     ; INITIALIZE FOR THE APPROXIMATE SIZE OF A SOYBEAN
0111 D2A3             69              SETB    P2.3             ; START A/D CONVERSION
0113 781E             70              MOV     UPTIME,#THREE_MILLISECONDS
0115 7978             71              MOV     DNTIME,#TWELEVE_MILLISECONDS
0117 858031           72              MOV     OFFSET,P0        ; INITIALIZE OFFSET
                      73
                      74     ;*************************************************************************
                      75     ;* START OF MAIN LOOP                                                    *
                      76     ;*   EXECUTES AT EVERY 100 MICROSECOND TICK FROM THE TIMER.               *
                      77     ;*************************************************************************
                      78     MAIN_LOOP:       ; THIS IS THE START OF THE MAIN LOOP.
011A C3               79              CLR     C                ; \
011B ED               80              MOV     A,UNIT_HI        ; :
011C 13               81              RRC     A                ; :
011D F533             82              MOV     HALF_UNIT_HI,A   ; : HALF_UNIT_DB <- (UNIT_DB / 2)
011F EE               83              MOV     A,UNTT_LO        ; :
0120 13               84              RRC     A                ; :
0121 F534             85              MOV     HALF_UNIT_LO,A   ; /
                      86
0123 308DFD           87     WAIT:    JNB     TF0,WAIT         ; \ WAIT HERE TILL 100 MICROSECOND TICK
0126 C28D             88              CLR     TF0              ; /
                      89
0128 C2A2             90     READ:    CLR     P2.2             ; ASSURANCE THAT "NOT READ" LINE IS LOW
012A C2A4             91              CLR     P2.4             ; ASSURANCE THAT CHIP SELECT LINE IS LOW
012C C2A3             92              CLR     P2.3             ; \ PULSE LOW THE "NOT WRITE" LINE TO START CONVERSION
012E D2A3             93              SETB    P2.3             ; /
0130 C3               94              CLR     C                ; \
0131 E531             95              MOV     A,OFFSET         ; : SIGNAL <- OFFSET - INPUT
0133 9580             96              SUBB    A,P0             ; :
0135 F532             97              MOV     SIGNAL,A         ; /
                      98
0137 403C             99              JC      SIG_NEG          ; JUMP IF SIGNAL IS NEGATIVE
0139 6034            100              JZ      SIG_ZERO         ; JUMP IS SIGNAL IS ZERO
                     101
                     102     SIG_POS:
013B 781E            103              MOV     UPTIME,#THREE_MILLISECONDS
013D D904            104              DJNZ    DNTIME,ADDPULSE ; JUMP AROUND IF NO CHANGE IN OFFSET NEEDED
013F 1531            105              DEC     OFFSET
0141 7978            106              MOV     DNTIME,#TWELEVE_MILLISECONDS
                     107     ADDPULSE:
```

```
MCS-51 MACRO ASSEMBLER    SEED21

LOC  OBJ            LINE     SOURCE
0143 EC              108              MOV     A,PULSE_LO        ; \
0144 2532            109              ADD     A,SIGNAL          ; :
0146 FC              110              MOV     PULSE_LO,A        ; :
0147 E4              111              CLR     A                 ; : PULSE_DB <- PULSE_DB + SIGNAL
0148 3B              112              ADDC    A,PULSE_HI        ; :
0149 FB              113              MOV     PULSE_HI,A        ; /
                     114
014A D53202          115              DJNZ    SIGNAL,NOT_1      ; \
014D 217D            116              AJMP    PULSE_DONE        ; : JUMP TO PULSE_DONE IF SIGNAL .EQ. (1 .OR. 2)
014F D53202          117     NOT_1:   DJNZ    SIGNAL,NOT_1_OR_2 ; :
0152 217D            118              AJMP    PULSE_DONE        ; /
                     119
                     120     NOT_1_OR_2:      ; TO GET TO THIS POINT A SEED PULSE IS PROBABLY OCCURING.
0154 D291            121              SETB    P1.1              ; SET FLAG TO INDICATE SEED DETECTION STARTED
0156 EB              122              MOV     A,PULSE_HI        ; \
0157 20E7C0          123              JB      ACC.7,MAIN_LOOP   ; :
015A C3              124              CLR     C                 ; :
015B EC              125              MOV     A,PULSE_LO        ; : JUMP TO MAIN_LOOP IF PULSE_DB .LT. (UNIT_DB / 2)
015C 9534            126              SUBB    A,HALF_UNIT_LO    ; :
015E EB              127              MOV     A,PULSE_HI        ; :
015F 9533            128              SUBB    A,HALF_UNIT_HI    ; :
0161 4087            129              JC      MAIN_LOOP         ; /
0163 B290            130              CPL     P1.0              ; OUTPUT 1 EDGE TO INDICATE 1 SEED SENSED
0165 0A              131              INC     QUAN
0166 A3              132              INC     DPTR              ; DEBUG
0167 EC              133              MOV     A,PULSE_LO        ; \
0168 9E              134              SUBB    A,UNIT_LO         ; :
0169 FC              135              MOV     PULSE_LO,A        ; : PULSE_DB <- PULSE_DB - UNIT_DB
016A EB              136              MOV     A,PULSE_HI        ; :
016B 9D              137              SUBB    A,UNIT_HI         ; :
016C FB              138              MOV     PULSE_HI,A        ; /
016D 211A            139              AJMP    MAIN_LOOP
                     140
                     141     SIG_ZERO:
016F 781E            142              MOV     UPTIME,#THREE_MILLISECONDS
0171 7978            143              MOV     DNTIME,#TWELEVE_MILLISECONDS
0173 217D            144              AJMP    PULSE_DONE
                     145
                     146     SIG_NEG:
0175 7978            147              MOV     DNTIME,#TWELEVE_MILLISECONDS
0177 D804            148              DJNZ    UPTIME,PULSE_DONE
0179 0531            149              INC     OFFSET
017B 781E            150              MOV     UPTIME,#THREE_MILLISECONDS
                     151
                     152     PULSE_DONE:  ; AT THIS POINT, SIGNAL IS ZERO, ONE, TWO, OR NEGATIVE (NO PULSE IS OCCURING)
017D 109102          153              JBC     P1.1,CONT         ; \ JUMP TO DONE IF NO SEED HAS STARTED
0180 411E            154              AJMP    DONE              ; /
0182 EB              155     CONT:    MOV     A,PULSE_HI        ; \
0183 20E713          156              JB      ACC.7,RECORD      ; :
0186 C3              157              CLR     C                 ; :
0187 EC              158              MOV     A,PULSE_LO        ; : JUMP AROUND IF PULSE_DB .LT. (UNIT_DB / 2)
0188 9534            159              SUBB    A,HALF_UNIT_LO    ; :
018A EB              160              MOV     A,PULSE_HI        ; :
018B 9533            161              SUBB    A,HALF_UNIT_HI    ; :
018D 400A            162              JC      RECORD            ; /
018F B290            163              CPL     P1.0              ; OUTPUT 1 EDGE TO INDICATE 1 SEED SENSED
0191 0A              164              INC     QUAN
```

```
MCS-51 MACRO ASSEMBLER     SEED21

LOC  OBJ         LINE    SOURCE
0192 A3           165              INC   DPTR              ; DEBUG
0193 EC           166              MOV   A,PULSE_LO        ; \
0194 9E           167              SUBB  A,UNIT_LO         ; :
0195 FC           168              MOV   PULSE_LO,A        ; :  PULSE_DB <- PULSE_DB - UNIT_DB
0196 EB           169              MOV   A,PULSE_HI        ; :
0197 9D           170              SUBB  A,UNIT_HI         ; :
0198 FB           171              MOV   PULSE_HI,A        ; /
                  172
0199 B4001A       173     RECORD:  CJNE  QUAN,#0,CONTO1    ; JUMP IF NOT A GLITCH
019C 7401         174     GLITCH:  MOV   A,#1              ; \
019E 253B         175              ADD   A,GLITCHES_LO     ; :
01A0 F53B         176              MOV   GLITCHES_LO,A     ; :  INCREMENT THE NUMBER OF GLITCHES FOUND      DEBUG
01A2 E4           177              CLR   A                 ; :
01A3 353A         178              ADDC  A,GLITCHES_HI     ; :
01A5 F53A         179              MOV   GLITCHES_HI,A     ; /
01A7 D53574       180              DJNZ  ZEROS,DONE        ; JUMP IF NOT TOO MANY GLITCHES FOUND
                  181
01AA C3           182     HALVE:   CLR   C                 ; \
01AB ED           183              MOV   A,TOTAL_HI        ; :
01AC 13           184              RRC   A                 ; :
01AD FD           185              MOV   TOTAL_HI,A        ; :
01AE EE           186              MOV   A,TOTAL_HI        ; :   TOTAL_TR <- TOTAL_TR / 2
01AF 13           187              RRC   A                 ; :    UNIT_DB <- UNIT_DB / 2
01B0 FE           188              MOV   TOTAL_HI,A        ; :
01B1 EF           189              MOV   A,TOTAL_LO        ; :
01B2 13           190              RRC   A                 ; :
01B3 FF           191              MOV   TOTAL_LO,A        ; /
01B4 4113         192              AJMP  OVERFLOWED
                  193
01B6 DA1F         194     CONTO1:  DJNZ  QUAN,CONTO2       ; JUMP IF NOT A SINGLE
01B8 7401         195     SINGLE:  MOV   A,#1              ; \
01BA 2530         196              ADD   A,SINGLES_LO      ; :
01BC F530         197              MOV   SINGLES_LO,A      ; :  INCREMENT THE NUMBER OF SINGLES FOUND       DEBUG
01BE E4           198              CLR   A                 ; :
01BF 353C         199              ADDC  A,SINGLES_HI      ; :
01C1 F53C         200              MOV   SINGLES_HI,A      ; /
                  201     AVERAGE:
01C3 EF           202              MOV   A,TOTAL_LO        ; \
01C4 2C           203              ADD   A,PULSE_LO        ; :
01C5 FF           204              MOV   TOTAL_LO,A        ; :
01C6 EE           205              MOV   A,TOTAL_HI        ; :
01C7 3B           206              ADDC  A,PULSE_HI        ; :
01C8 FE           207              MOV   TOTAL_HI,A        ; :  TOTAL_TR <- TOTAL_TR + PULSE_DB
01C9 E4           208              CLR   A                 ; :
01CA 8BF0         209              MOV   B,PULSE_HI        ; :
01CC 30F701       210              JNB   B.7,AROUND        ; :
01CF F4           211              CPL   A                 ; :
01D0 3D           212     AROUND:  ADDC  A,TOTAL_HI        ; :
01D1 FD           213              MOV   TOTAL_HI,A        ; /
01D2 D53649       214              DJNZ  ONES,DONE
01D5 4113         215              AJMP  OVERFLOWED        ; ENOUGH SINGLES WERE FOUND TO BE CONSIDERED LOCKED-ON
                  216
01D7 DA10         217     CONTO2:  DJNZ  QUAN,CONTO3       ; JUMP IF NOT A DOUBLE
01D9 7401         218     DOUBLE:  MOV   A,#1              ; \
01DB 253F         219              ADD   A,DOUBLES_LO      ; :
01DD F53F         220              MOV   DOUBLES_LO,A      ; :  INCREMENT THE NUMBER OF DOUBLES FOUND       DEBUG
01DF E4           221              CLR   A                 ; :
```

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LOC  OBJ           LINE     SOURCE
01E0 353E           222              ADDC    A,DOUBLES_HI       ; :
01E2 F53E           223              MOV     DOUBLES_HI,A       ; /
01E4 D53737         224              DJNZ    TWOS,DONE
01E7 4109           225              AJMP    TWICE              ; TOO MANY DOUBLES FOUND
                    226
01E9 DA10           227     CONT03:  DJNZ    QUAN,QUAD          ; JUMP IF NOT A TRIPLE
01EB 7401           228     TRIPLE:  MOV     A,#1               ; \
01ED 2541           229              ADD     A,TRIPLES_LO       ; :
01EF F541           230              MOV     TRIPLES_LO,A       ; :  INCREMENT THE NUMBER OF TRIPLES FOUND       DEBUG
01F1 E4             231              CLR     A                  ; :
01F2 3540           232              ADDC    A,TRIPLES_HI       ; :
01F4 F540           233              MOV     TRIPLES_HI,A       ; /
01F6 D53825         234              DJNZ    THREES,DONE
01F9 2109           235              AJMP    DOUBLE             ; TOO MANY TRIPLES FOUND
                    236
01FB 7401           237     QUAD:    MOV     A,#1               ; \
01FD 2543           238              ADD     A,QUADRUPLES_LO    ; :
01FF F543           239              MOV     QUADRUPLES_LO,A    ; :  INCREMENT THE NUMBER OF QUADRUPLES FOUND    DEBUG
0201 E4             240              CLR     A                  ; :
0202 3542           241              ADDC    A,QUADRUPLES_HI    ; :
0204 F542           242              MOV     QUADRUPLES_HI,A    ; /
0206 D53915         243              DJNZ    FOURS,DONE         ; JUMP IF TOO MANY QUADRUPLES AND ABOVE FOUND
                    244
0209 C3             245     TWICE:   CLR     C                  ; \
020A EF             246              MOV     A,TOTAL_LO         ; :
020B 33             247              RLC     A                  ; :
020C FF             248              MOV     TOTAL_LO,A         ; :
020D EE             249              MOV     A,TOTAL_HI         ; :   TOTAL_TR <- TOTAL_TR * 2
020E 33             250              RLC     A                  ; :    UNIT_DB <- UNIT_DB * 2
020F FE             251              MOV     TOTAL_HI,A         ; :
0210 ED             252              MOV     A,TOTAL_HI         ; :
0211 33             253              RLC     A                  ; :
0212 FD             254              MOV     TOTAL_HI,A         ; /
                    255
                    256     OVERFLOWED:
0213 E4             257              CLR     A
0214 F535           258              MOV     ZEROS,A
0216 F536           259              MOV     ONES,A
0218 F537           260              MOV     TWOS,A
021A F538           261              MOV     THREES,A
021C F539           262              MOV     FOURS,A
021E 7800           263     DONE:    MOV     PULSE_HI,#0
0220 7C00           264              MOV     PULSE_LO,#0
0222 7A00           265              MOV     QUAN,#0
0224 211A           266              AJMP    MAIN_LOOP
                    267
                    268              END
```

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MCS-51 MACRO ASSEMBLER    SEED21

XREF SYMBOL TABLE LISTING
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N A M E            T Y P E   V A L U E    ATTRIBUTES AND REFERENCES
ACC. . . . . . . . D ADDR    00E0H   A     123 156
ADDPULSE . . . . . C ADDR    0143H   A     104 107#
AROUND . . . . . . C ADDR    0100H   A     210 212#
AVERAGE. . . . . . C ADDR    01C3H   A     201#
B. . . . . . . . . D ADDR    00F0H   A     209 210
CONT . . . . . . . C ADDR    0182H   A     153 155#
CONT01 . . . . . . C ADDR    01B6H   A     173 194#
CONT02 . . . . . . C ADDR    01D7H   A     194 217#
CONT03 . . . . . . C ADDR    01E9H   A     217 227#
DNTIME . . . . . .   REG     R1            13# 71 104 106 143 147
DONE . . . . . . . C ADDR    021EH   A     154 180 214 224 234 243 263#
DOUBLE . . . . . . C ADDR    0109H   A     218# 235
DOUBLES_HI . . . . D ADDR    003EH   A     41# 222 223
DOUBLES_LO . . . . D ADDR    003FH   A     42# 219 220
DOUBLES. . . . . . D ADDR    003EH   A     40# 41 42
FOURS. . . . . . . D ADDR    0039H   A     33# 243 262
GLITCH . . . . . . C ADDR    019CH   A     174#
GLITCHES_HI. . . . D ADDR    003AH   A     35# 178 179
GLITCHES_LO. . . . D ADDR    003BH   A     36# 175 176
GLITCHES . . . . . D ADDR    003AH   A     34# 35 36
HALF_UNIT_HI . . . D ADDR    0033H   A     27# 82 128 161
HALF_UNIT_LO . . . D ADDR    0034H   A     28# 85 126 159
HALVE. . . . . . . C ADDR    01AAH   A     182#
INITIALIZE . . . . C ADDR    010FH   A     67#
LOOP . . . . . . . C ADDR    0103H   A     58# 59
MAIN_LOOP. . . . . C ADDR    011AH   A     78# 123 129 139 266
NOT_1_OR_2 . . . . C ADDR    0154H   A     117 120#
NOT_1. . . . . . . C ADDR    014FH   A     115 117#
OFFSET . . . . . . D ADDR    0031H   A     25# 72 95 105 149
ONES . . . . . . . D ADDR    0036H   A     30# 214 259
OVERFLOWED . . . . C ADDR    0213H   A     192 215 256#
P0 . . . . . . . . D ADDR    0080H   A     72 96
P1 . . . . . . . . D ADDR    0090H   A     121 130 153 163
P2 . . . . . . . . D ADDR    00A0H   A     69 90 91 92 93
PULSE_DONE . . . . C ADDR    017DH   A     116 118 144 148 152#
PULSE_HI . . . . .   REG     R3            15# 112 113 122 127 136 138 155 160 169 171 206 209 263
PULSE_LO . . . . .   REG     R4            16# 108 110 125 133 135 158 166 168 203 264
QUAD . . . . . . . C ADDR    01FBH   A     227 237#
QUADRUPLES_HI. . . D ADDR    0042H   A     47# 241 242
QUADRUPLES_LO. . . D ADDR    0043H   A     48# 238 239
QUADRUPLES . . . . D ADDR    0042H   A     46# 47 48
QUAN . . . . . . .   REG     R2            14# 131 164 173 194 217 227 265
READ . . . . . . . C ADDR    0128H   A     90#
RECORD . . . . . . C ADDR    0199H   A     156 162 173#
SIG_NEG. . . . . . C ADDR    0175H   A     99 146#
SIG_POS. . . . . . C ADDR    0138H   A     102#
SIG_ZERO . . . . . C ADDR    016FH   A     100 141#
SIGNAL . . . . . . D ADDR    0032H   A     26# 97 109 115 117
SINGLE . . . . . . C ADDR    01B8H   A     195#
SINGLES_HI . . . . D ADDR    003CH   A     38# 199 200
SINGLES_LO . . . . D ADDR    003DH   A     39# 196 197
SINGLES. . . . . . D ADDR    003CH   A     37# 38 39
START. . . . . . . C ADDR    0100H   A     53 56#
```

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N A M E                   T Y P E    V A L U E     ATTRIBUTES AND REFERENCES
TEMP . . . . . . . . .    D ADDR     0030H    A      24#
TFO. . . . . . . . . .    B ADDR     0088H.5  A      87 88
THO. . . . . . . . . .    D ADDR     008CH    A      63
THREE_MILLISECONDS .        NUMB     001EH    A      9# 70 103 142 150
THREES . . . . . . . .    D ADDR     0038H    A      32# 234 261
THOD . . . . . . . . .    D ADDR     0089H    A      64
TOTAL_HI . . . . . . .      REG      R5              17# 20 183 185 212 213 252 254
TOTAL_LO . . . . . . .      REG      R7              19# 189 191 202 204 246 248
TOTAL_MI . . . . . . .      REG      R6              18# 21 186 188 205 207 249 251
TRO. . . . . . . . . .    B ADDR     0088H.4  A      65
TRIPLE . . . . . . . .    C ADDR     01EBH    A      228#
TRIPLES_HI . . . . . .    D ADDR     0040H    A      44# 232 233
TRIPLES_LO . . . . . .    D ADDR     0041H    A      45# 229 230
TRIPLES. . . . . . . .    D ADDR     0040H    A      43# 44 45
TWELEVE_MILLISECONDS        NUMB     0078H    A      10# 71 106 143 147
TWICE. . . . . . . . .    C ADDR     0209H    A      225 245#
TWOS . . . . . . . . .    D ADDR     0037H    A      31# 224 260
UNIT_HI. . . . . . . .      REG      R5              20# 61 68 80 137 170
UNIT_LO. . . . . . . .      REG      R6              21# 83 134 167
UPTIME . . . . . . . .      REG      R0              12# 70 103 142 148 150
WAIT . . . . . . . . .    C ADDR     0123H    A      87# 87
ZEROS. . . . . . . . .    D ADDR     0035H    A      29# 180 258

REGISTER BANK(S) USED: 0
ASSEMBLY COMPLETE, NO ERRORS FOUND
```

Claims

1. A signal processing system for an article sensor which provides a signal (INPUT) which varies substantially linearly with the number of articles within the sensor, with means which perform the following processing operations:
repetitively increment an area value (PULSE) indicative of a pulse area by a value (SIGNAL) derived from the sensor signal (INPUT),
repetitively compare the area value (PULSE) with a threshold value (HALF UNIT) and generate an output signal (P1.0) when the area value (PULSE) is not less than the threshold value (HALF UNIT), and
decrease the area value (PULSE), when the output signal (P1.0) is generated, by an estimated area value (UNIT) related to the passage of one article through the sensor,
characterized in that the number (QUAN) of articles passing through the sensor a group is counted (132) and the estimated area value (UNIT) is significantly reduced (178) and significantly increased (172) when there is a high frequency of occurrences of zero and multiple values respectively of the said number

2. A system according to claim 1, characterized in that the estimated area value (UNIT) is a more significant portion of a further value (TOTAL) which is increased or reduced (180) by the rer area value (PULSE) established when the area value has been decreased by the estimated area value (UNIT) in response to the output signal (P1.0).

3. A system according to claim 1 or claim 2, characterized in that the number (QUAN) of articles passing through the sensor in a group is counted (132) and the estimated area value (UNIT) is significantly reduced (178) and significantly increased (172) when there is a high frequency of occurrences of zero and multiple values respectively of the said number (QUAN).

4. A system according to any of claims 1 to 3, characterized in that the derived value (SIGNAL) is formed by subtracting the sensor signal (INPUT) from an offset value (OFFSET) representing the steady-state magnitude of the sensor signal when no article is passing through the sensor.

5. A system according to claim 1, characterized in that the offset value (OFFSET) is incremented when the derived value (SIGNAL) is negative for a predetermined period of time and is decremented when the derived value (SIGNAL) is positive for a predetermined period of time.

6. A system according to any of claims 1 to 5, characterized in that the threshold value (HALF UNIT) is a predetermined fraction of the estimated area value (UNIT).

7. A system according to any of claims 1 to 6, characterized in that the sensor signal (INPUT) represents the amount of radiation unobscured by articles passing through the sensor and reaching a radiation detector.

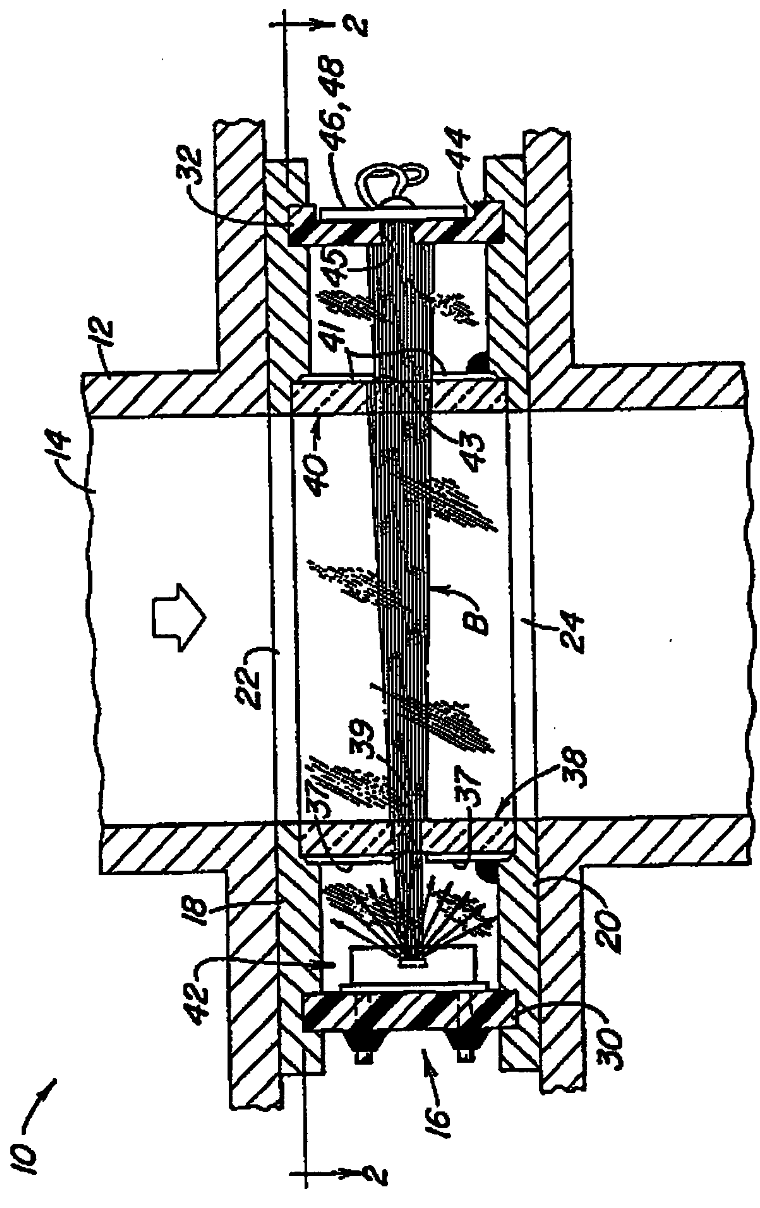

FIG. 1

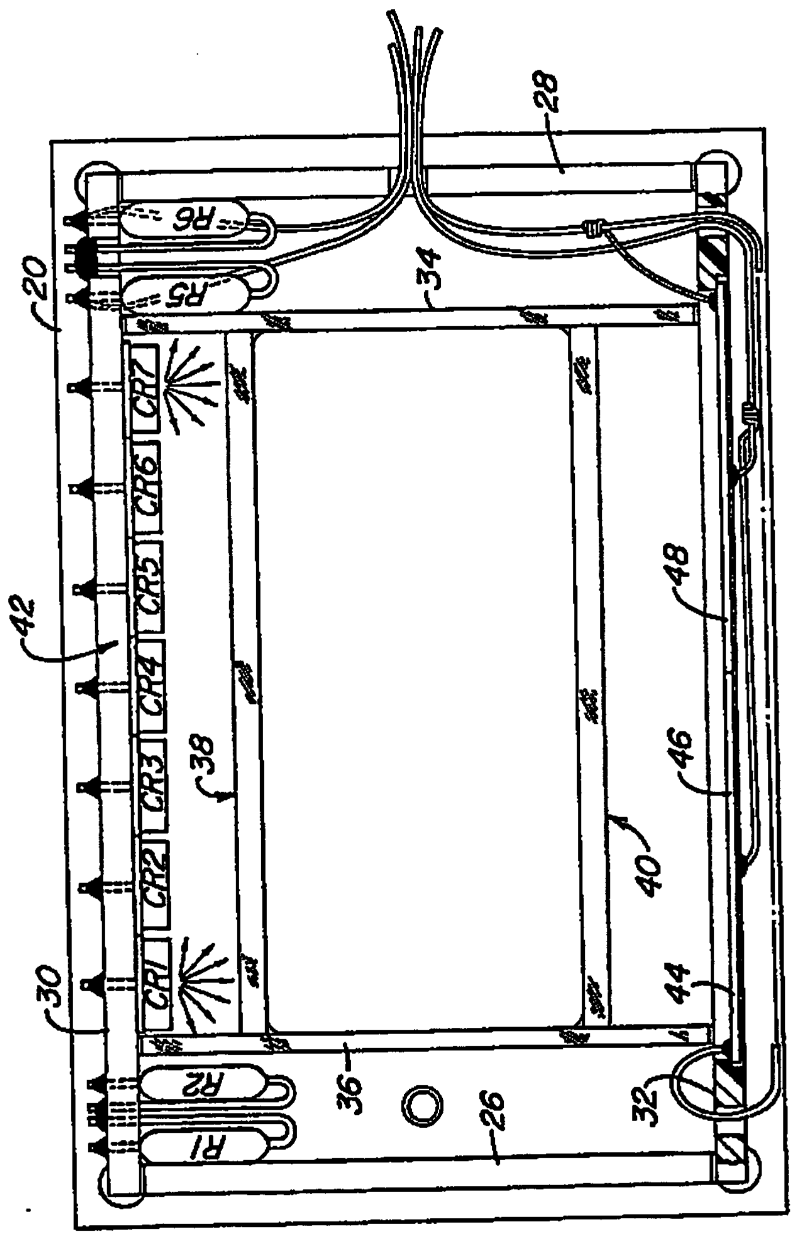
20
42
30
38
34
28
48
46
40
44
36
26
32
R1
R2
R5
R6
CR1
CR2
CR3
CR4
CR5
CR6
CR7

FIG. 2

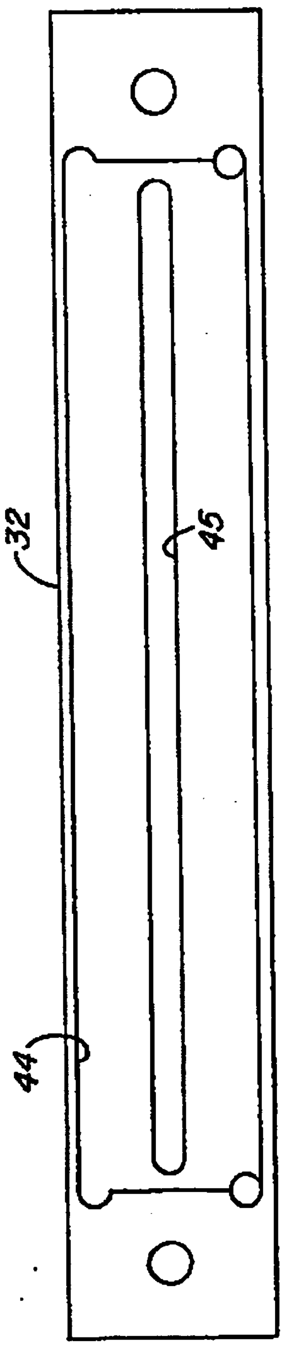

FIG. 3

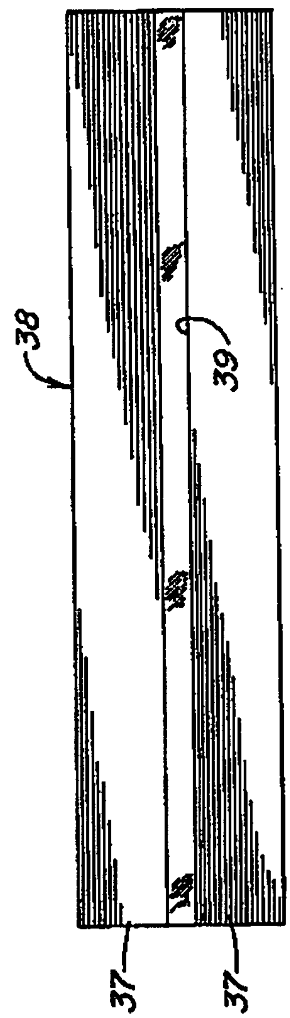

FIG. 4

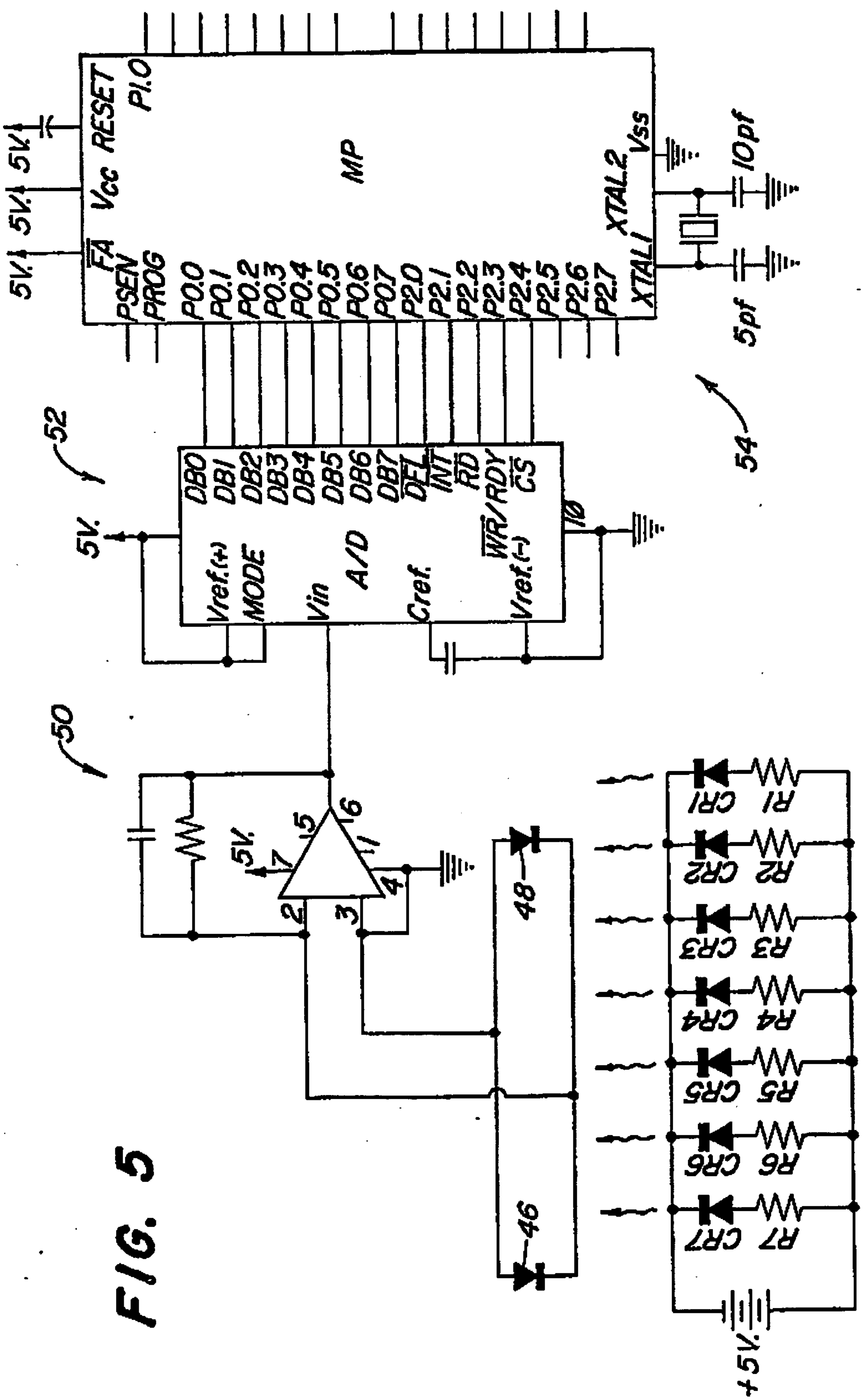
5V.
5V.
5V.
5V.
RESET
Vcc
FA
PSEN
PROG
P0.0
P0.1
P0.2
P0.3
P0.4
P0.5
P0.6
P07
P2.0
P2.1
P2.2
P2.3
P2.4
P2.5
P2.6
P2.7
XTAL1
XTAL2
Vss
P1.0
MP
10pf
5pf
54
52
5V.
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
DEL
INT
RD
WR/RDY
CS
Vref.(+)
MODE
Vin
A/D
Cref.
Vref.(-)
10
50
5V.
7
5
6
1
4
3
2
48
46
CR1
CR2
CR3
CR4
CR5
CR6
CR7
R1
R2
R3
R4
R5
R6
R7
+5V.

FIG. 5

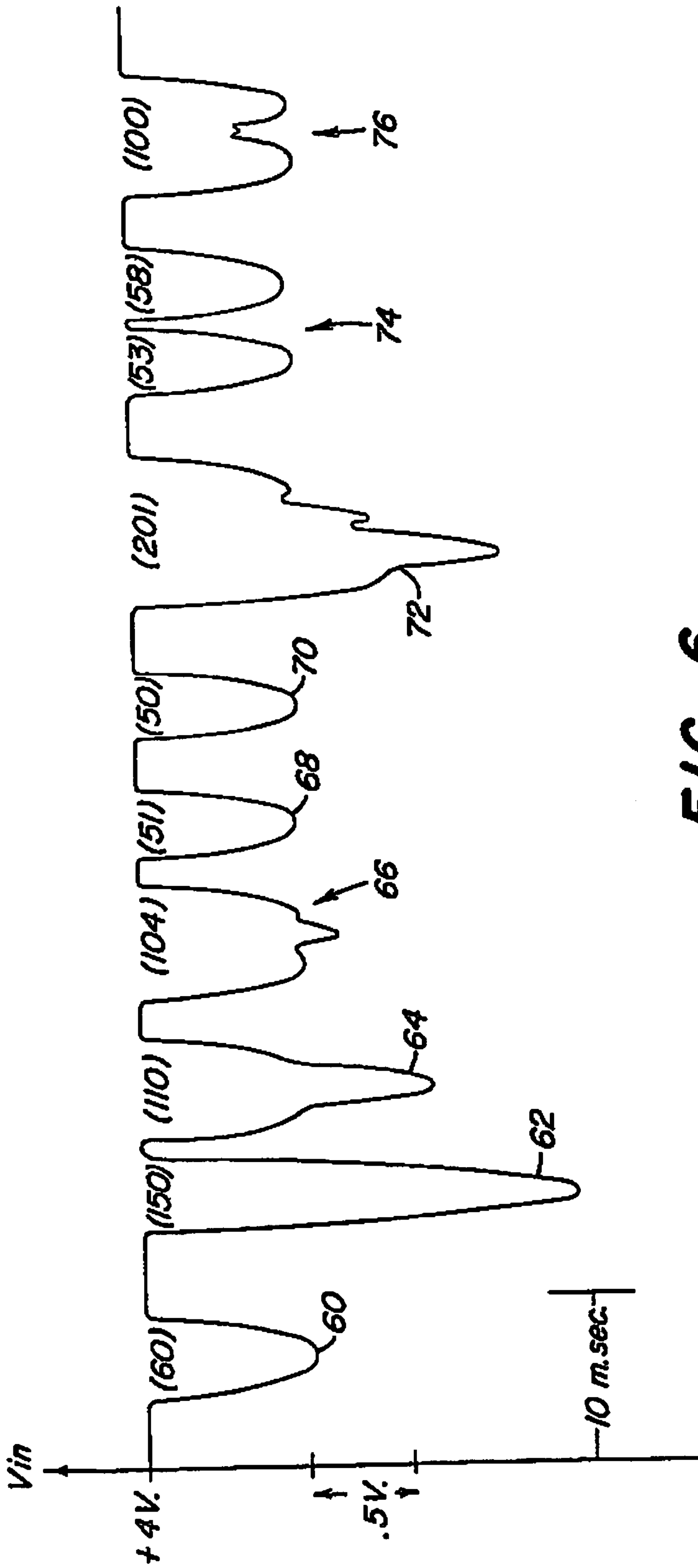
Vin
+4V.
.5V.
10 m.sec.
(60)
(150)
(110)
(104)
(51)
(50)
(201)
(53)
(58)
(100)
60
62
64
66
68
70
72
74
76

FIG. 6

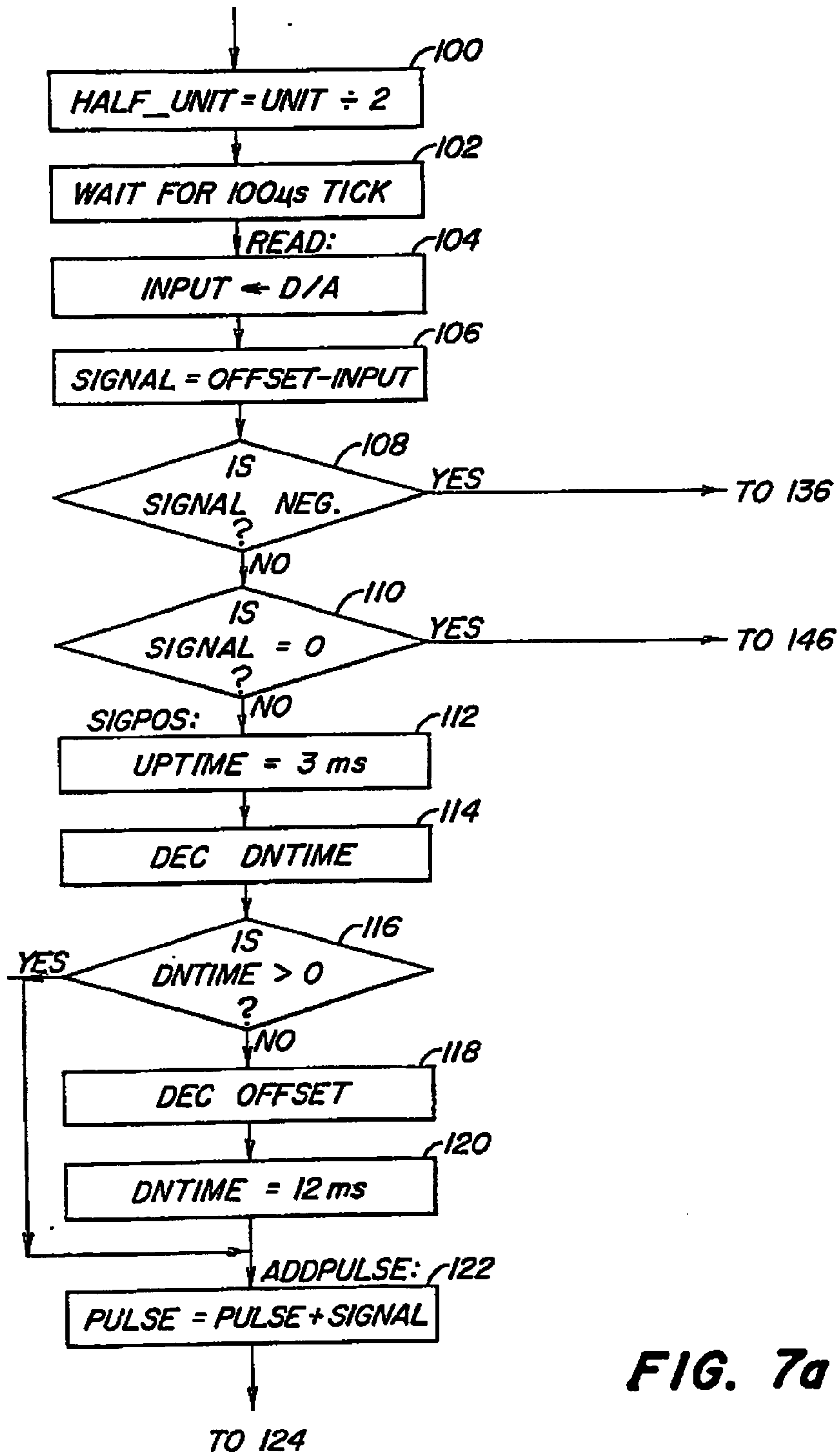
100
HALF_UNIT = UNIT ÷ 2
102
WAIT FOR 100μs TICK
READ:
104
INPUT ← D/A
106
SIGNAL = OFFSET-INPUT
108
IS SIGNAL NEG. ?
YES
TO 136
NO
110
IS SIGNAL = 0 ?
YES
TO 146
NO
SIGPOS:
112
UPTIME = 3 ms
114
DEC DNTIME
116
IS DNTIME > 0 ?
YES
NO
118
DEC OFFSET
120
DNTIME = 12 ms
ADDPULSE:
122
PULSE = PULSE + SIGNAL
TO 124

FIG. 7a

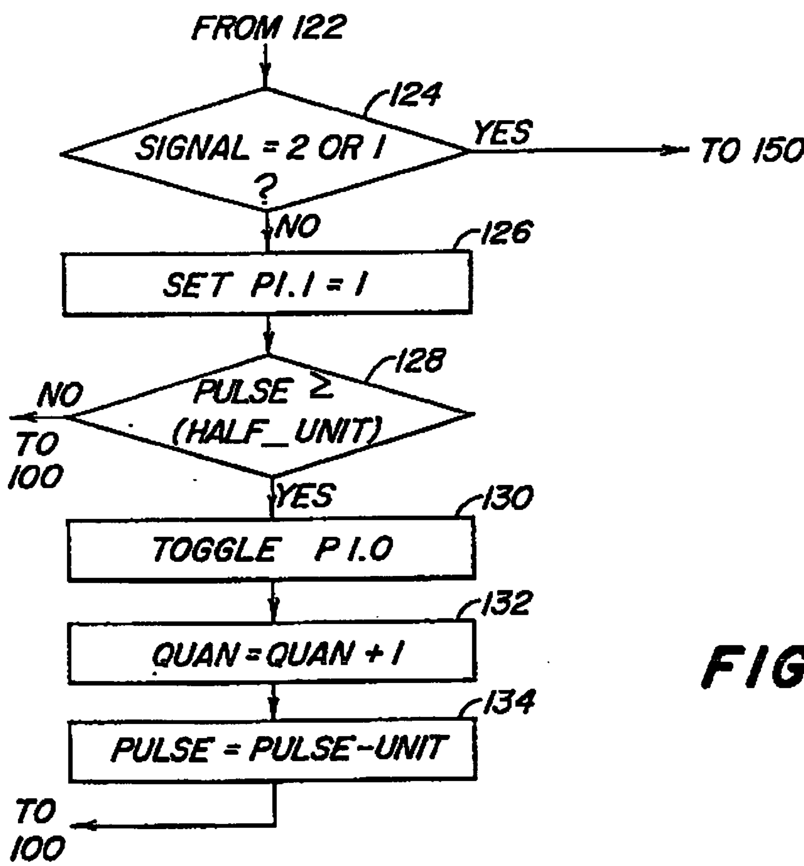
FROM 122
124
SIGNAL = 2 OR 1
?
YES
TO 150
NO
126
SET P1.1 = 1
128
PULSE ≥
(HALF_UNIT)
NO
TO
100
YES
130
TOGGLE P1.0
132
QUAN = QUAN + 1
134
PULSE = PULSE-UNIT
TO
100

FIG. 7b

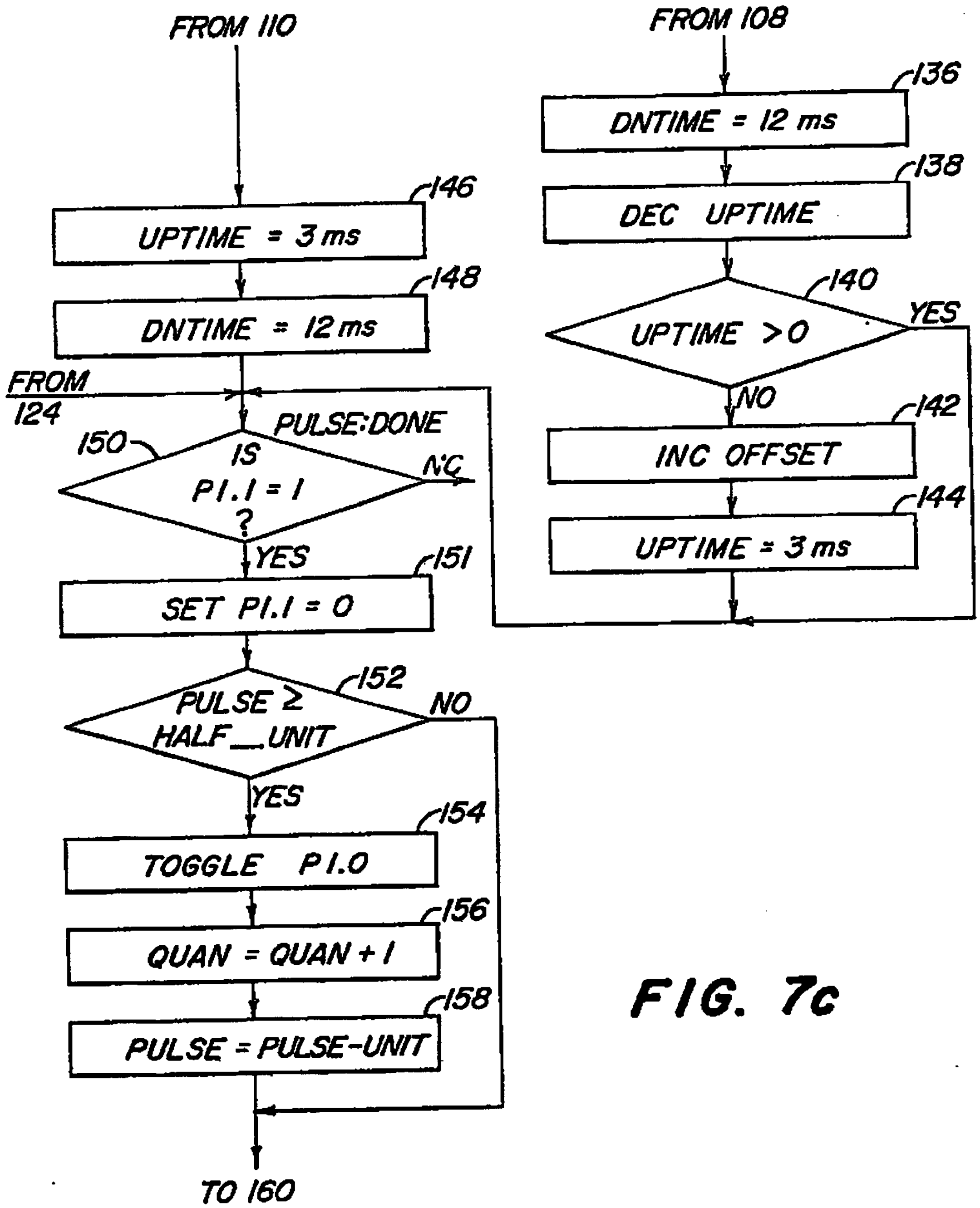
FROM 110
FROM 108
136
DNTIME = 12 ms
138
DEC UPTIME
146
UPTIME = 3 ms
148
DNTIME = 12 ms
140
UPTIME > 0
YES
NO
FROM 124
142
INC OFFSET
PULSE:DONE
150
IS P1.1 = 1 ?
NO
144
UPTIME = 3 ms
YES
151
SET P1.1 = 0
152
PULSE ≥ HALF_UNIT
NO
YES
154
TOGGLE P1.0
156
QUAN = QUAN + 1
158
PULSE = PULSE-UNIT
TO 160

FIG. 7c

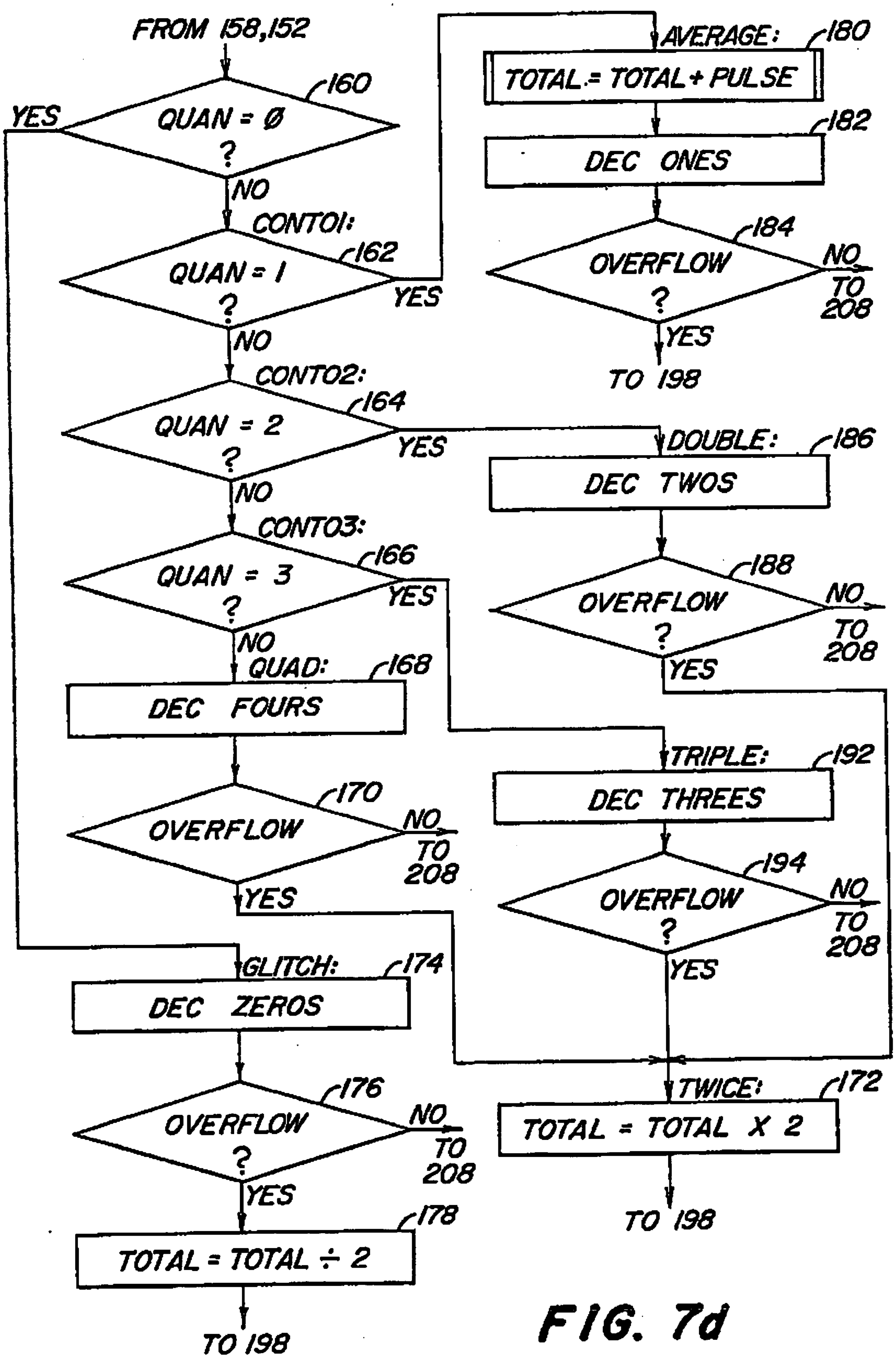
FROM 158,152
160
QUAN = Ø ?
YES
NO
CONT01:
162
QUAN = 1 ?
YES
NO
CONT02:
164
QUAN = 2 ?
YES
NO
CONT03:
166
QUAN = 3 ?
YES
NO
QUAD:
168
DEC FOURS
170
OVERFLOW
NO
TO 208
YES
GLITCH:
174
DEC ZEROS
176
OVERFLOW ?
NO
TO 208
YES
178
TOTAL = TOTAL ÷ 2
TO 198
AVERAGE:
180
TOTAL = TOTAL + PULSE
182
DEC ONES
184
OVERFLOW ?
NO
TO 208
YES
TO 198
DOUBLE:
186
DEC TWOS
188
OVERFLOW ?
NO
TO 208
YES
TRIPLE:
192
DEC THREES
194
OVERFLOW ?
NO
TO 208
YES
TWICE:
172
TOTAL = TOTAL X 2
TO 198

FIG. 7d

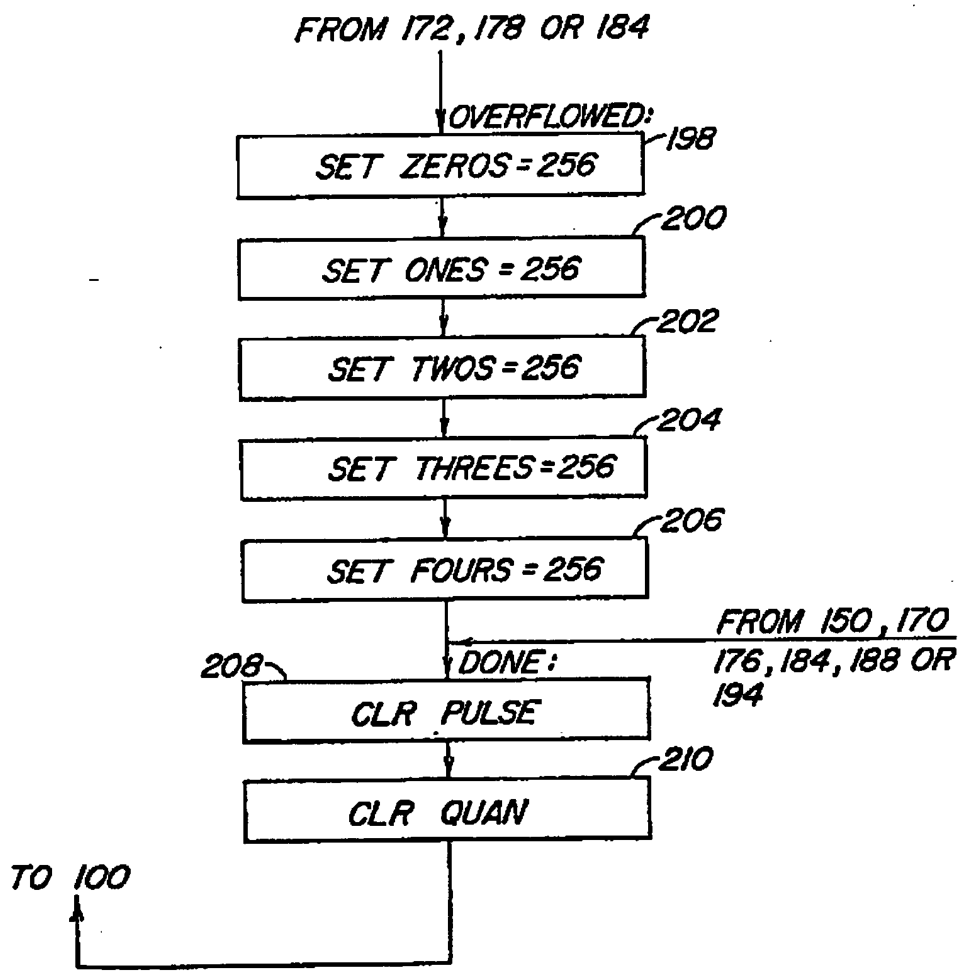
FROM 172, 178 OR 184
OVERFLOWED:
SET ZEROS = 256
198
SET ONES = 256
200
SET TWOS = 256
202
SET THREES = 256
204
SET FOURS = 256
206
FROM 150, 170
176, 184, 188 OR
194
DONE:
208
CLR PULSE
CLR QUAN
210
TO 100

FIG. 7e

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